وزارة الصحة
Ministry of Health

Adult Electrolyte Replacement Therapy Protocol

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1. Introduction

1.1 Background

- Electrolyte and fluid disturbances are common conditions in patients of unstable status caused by:
  1- alterations in fluids and electrolytes due to:
    - absorption,
    - distribution, or
    - execration; [1]
  2- any changes in the hormonal and hemostatic processes and fluid status; or[1]
  3- medications. [1]
- Electrolyte and fluid abnormalities may lead to significant adverse clinical effects such as:
    - cardiac arrest,
    - arrhythmias,
    - skeletal muscle weakness,
    - respiratory muscle weakness,
    - respiratory failure,
    - convulsions, or
    - delirium.[2]
- Patients need frequent evaluation and monitoring of their electrolyte and fluid homeostasis during replacement therapy.[1]

1.2 Aim and Scope

1. Enhance adult patient care
2. Ensure efficacy and safety of electrolyte replacement therapy in ill patients
3. Standardize electrolyte replacement protocols in order to reduce possible errors in medication prescribing, preparing, dispensing, transcribing, administration, and monitoring and reduce costs from medication waste
4. Determine the appropriate correction dose based on individual lab rates and patient clinical status
5. Ensure monitoring of patient parameters needed to be measured while correcting imbalance.
6. Determine the monitoring time of each electrolyte after replacement
7. Assessing the effects of electrolytes on other electrolyte homeostasis before starting replacement
8. Facilitate the most effective and safest way of electrolyte replacement to ensure best patient outcomes through the implementation of this protocol by health care workers.

1.3 Health Care Workers Responsible for Implementing this Protocol in MOH Hospitals

1- Physicians
2- Pharmacists
3- Nurses

1.4 Targeted Population

All adult patients, excluding patients with the following:

- renal insufficiency (eGFR less than 20 mL/min/1.73m^2)
- diabetic ketoacidosis (DKA)
- urine output less than 0.5 mL/kg/hr
- patients on dialysis
- chronic adrenal insufficiency
- electrical burn
- rhabdomyolysis

1.5 Settings

MOH hospitalized patients

1.6 Methodology

This protocol was prepared based on available evidence for the management of electrolytes disturbance, including but not limited to guidance from: American College of Clinical Pharmacy (ACCP), Pharmacotherapy, literature review, and the MOH formulary. The protocol was reviewed by several MOH consultant clinical pharmacists specialized in intensive care unit (ICU), parenteral nutrition; nurses; and ICU consultant physicians.

1.7 Conflict of Interest

No conflicts of interest

1.8 Funding Source

None

1.9 Updating

The protocol will be updated according to updates in the national and international evidence for the management of electrolyte disturbances or updates in the MOH formulary, and this will be done every three years.

2. Management of Common Electrolyte Disturbances

2.1 Hypokalemia

2.1.1 Background

- Hypokalemia is defined as a serum potassium (K^+) concentration less than 3.5 mEq/L [mmol/L].[3]
- Normal serum K^+ levels: 3.5–5.2 mEq/L.[3]
- Potassium is an intracellular electrolyte. [3]
- Hypokalemia is a commonly encountered electrolyte abnormality in clinical practice.[4]

- **Hypokalemia is often categorized as:**
  - Mild (serum potassium 3.1–3.5 mEq/L [mmol/L])
  - Moderate (serum potassium 2.5–3 mEq/L [mmol/L])
  - Severe (less than 2.5 mEq/L [mmol/L]) [4]

2.1.2 Available intravenous (IV) products[15]

- Potassium chloride (KCl) 15%: contains potassium 2 mEq (mmol) /mL.
- Potassium acetate: contains potassium 2 mEq (mmol)/mL and acetate 2 mEq (mmol)/mL.
- Potassium phosphate: contains potassium 4.4 mEq (mmol)/mL and phosphate 3 mmol/mL.

2.1.3 General Approach to Hypokalemia Treatment

If the K^+ level is less than 3.5 mEq/L

✓ The underlying cause of hypokalemia should be identified and corrected.[3]
✓ Check magnesium level (magnesium status can influence potassium homeostasis).[3][5][6]
✓ Choose the appropriate replacement form as follows:

- Always use oral replacement (DO NOT grind slow-release tablets) whenever possible. IV potassium should be used for patients who are unable to swallow or are NPO or if K^+ level is less than 3.[11]
- Use potassium chloride if the patient has metabolic alkalosis with gastrointestinal losses (as is usually seen with vomiting) or in patients with a normal serum bicarbonate concentration. [8][9][10]
- Use potassium acetate in the presence of metabolic acidosis (e.g. with diarrhea or renal tubular acidosis).[8][9][10]
- Always look at the phosphate level to determine the appropriate K^+ product: KCl, KPO_4.[7]

2.1.4 Standard Concentrations

- **Dosing of potassium supplementation should be written in mmol (not grmas or mEq) to avoid potential medication errors**
- 20 mmol /250 mL NS for **peripheral line (Maximum concentration 10 mmol/100 mL)**
- 20 mmol /100 mL NS for **Central line (Maximum concentration 40 mmol/100 mL)**

2.1.5 Infusion Rate

- ✓ **All Potassium infusions must be administered via infusion pumps.**
  - **Peripheral access:** infuse at a rate of 10 mmol /hr.[2]
  - **Central access:** infuse at a rate of 20 mmol/hr with continuous ECG monitoring. If serum K^+ level is < 2.5 ➔ 40 mmol/hr may be given with continuous cardiac monitoring.
- ✓ Potassium must be diluted before administration (Table 2).[7]
- ✓ It is preferable to keep the patient's K^+ level at 4.0 mEq/L or greater, if possible.[3]
- ✓ Approximately every 10 mmol of potassium given increases serum level by about 0.1 mEq/L.
- ✓ A decrease of 1 mEq/L in serum K^+ represents a K^+ deficit of approximately 200 to 400 mEq.[13]
- ✓ If creatinine clearance (CrCL) <30 mL/min, reduce the dose by 50% (refer to Tables 1, 2). [12]

2.1.6 Oral or Enteral Potassium Replacement in Asymptomatic Patients?

Table 1: Oral or Enteral Potassium Replacement in Asymptomatic Patients? [7]

Serum K^+ level	Total K^+ replacement (normal renal function)	If CrCL<30 mL/min reduce the dose	Recheck level
3.7 – 3.8 mEq/L	40 mmol stat	No need for replacement	With morning labs, obtain basic metabolic panel
3.4 – 3.6 mEq/L	40 mmol stat	20 mmol stat	6-hours after replacement; if K^+ still low give another 40 mmol stat and repeat with next lab; with next morning labs add magnesium, obtain basic metabolic panel
3.0 – 3.3 mEq/L	Give 40 mmol stat If still under 3.5 give another dose then repeat the result	20 mmol stat	
If serum level < 3.0 mmol/L call physician and consider IV replacement			

Abbreviations: CrCL, creatinine clearance.

2.1.7 IV Potassium Replacement:

Table 2: Intravenous Potassium (K^+) Replacement [7]

Serum K^+ level mEq/L mmol/L	Central line under continuous ECG monitoring	Peripheral line	If CrCL<30 mL/min		Recheck Level
			Central line under continuous ECG monitoring	Peripheral line	
3.6 – 3.8	20 mmol K^+ in 100 mL NS over 1 hr	20 mmol K^+ in 250 mL NS over 2 hr	Not recommended		With morning labs, obtain basic metabolic panel
3.0 – 3.5	40 mmol K^+ in 200 mL NS over 2 hr	40 mmol K^+ in 500 mL NS over 4 hr	20 mmol K^+ in 100 mL NS over 1 hr	20 mmol K^+ in 250 mL NS over 2 hr	Recheck the level 2-hours after replacement and reassess, also with next morning labs add magnesium and basic metabolic panel
2.5 – 2.9	60 mmol K^+ in 300 mL NS over 3 hr	40 mmol K^+ in 500 mL NS over 4 hr followed by 20 mmol K^+ in 250 mL NS for 2 hr	20 mmol K^+ in 100 mL NS over 2 hr, then recheck the level 2-hours after replacement	20 mmol K^+ in 250 mL NS over 2 hr, then recheck the level 2-hours after replacement	2-hours after replacement and adjust treatment accordingly
< 2.5 or symptomatic	40 mmol K^+ in 100 mL NS over 1 hr	40 mmol K^+ in 500 mL NS over 4 hr	40 mmol K^+ in 200 mL NS over 2 hr	40 mmol K^+ in 500 mL NS over 4 hr	After each 40 mmol replacement and adjust treatment accordingly

Abbreviations: CrCL, creatinine clearance; NS, normal saline.

2.2 Hypomagnesemia [3][7][16-17]

2.2.1 General Approach to Hypomagnesemia Treatment

- ✓ Hypomagnesemia is diagnosed when magnesium (Mg^{2+}) is <0.65 mmol /L.
- ✓ Normal serum Mg^{2+} levels: 1.8 – 2.4 mg/dL (0.75 – 1.01 mmol/L)
- ✓ The underlying cause of hypomagnesemia should be identified and corrected.
- ✓ Approximately every 8 mmol of magnesium given increases serum level by about 0.1 mmol/L.
- ✓ Serum concentration of Mg^{2+} may be slightly falsely lowered in the presence of significant hypoalbuminemia (in severe hypoalbuminemia the value should be corrected by adding 0.05 mmol/L for each 1 g/dL (10 g/L) of reduction in the plasma albumin level below 4 g/dL [40 g/L])
- ✓ Magnesium replacement should be performed over 4 to 5 days, and continued supplementation should be provided for patients unable to eat.
- ✓ ICU target serum Mg^{2+} concentration is > 2 mg/ dL (0.8 mmol/L).
- ✓ Magnesium supplementation can be given by the oral, intramuscular (IM), or IV routes. The severity of the magnesium depletion and the presence of severe signs and symptoms should dictate the route of administration.
    - Magnesium replacement in patients with no or minimal symptoms of hypomagnesemia who are able to tolerate oral Mg^{2+} should be orally.
    - IM administration is painful, and should be reserved for patients with severe hypomagnesemia and limited venous access.
    - IV bolus administration is associated with flushing, sweating, and a sensation of warmth; thus, bolus administration **with Emergency Situations** must be diluted first and not be given faster than 150 mg/minute (0.6 mmol/minute).
- ✓ Magnesium depletion can influence potassium and calcium homeostasis. Additionally, because calcium forms a complex with the sulfate moiety, which is then excreted, large amounts of IV magnesium sulfate should be administered with caution to hypocalcemia patients, as it can further exacerbate calcium deficiency.
- ✓ Magnesium sulphate ($MgSO_4$): 1 mmol = 2 mEq = 24 mg of elemental magnesium = 240 mg.
- ✓ Intravenous magnesium sulphate 50% (1 g/ 2 mL) contains 4 mEq (2 mmol)/mL.
- ✓ Intravenous magnesium sulphate 10% (1 g/ 10 mL) contains 0.8 mEq (0.4 mmol)/mL.

Table 3: Renal Magnesium Retention Test

Indications: 1- For suspected Mg^{2+} deficiency when serum Mg^{2+} is normal 2- For identifying the end point of Mg^{2+} replacement therapy
Contraindications: 1- Renal failure 2- Ongoing renal magnesium wasting
Protocol: 1- Add 24 mmol of magnesium (6 g of $MgSO_4$) to 250 mL normal saline and infuse over 1 hour.

2- Collect urine for 24 hours, beginning at the onset of the magnesium infusion.

Results:

A- For suspected Mg^{2+} deficiency

1. Urinary Mg^{2+} excretion <12 mmol (24 mEq) in 24 hours (i.e. < 50% of infused Mg^{2+}) is evidence of Mg^{2+} depletion.
2. Urinary Mg^{2+} excretion >19 mmol (38 mEq) in 24 hours (i.e. >80% of infused Mg^{2+}) is evidence agonist Mg^{2+} depletion.

B- For the end point of Mg^{2+} replacement therapy

Mg^{2+} replacement is continued until urinary Mg^{2+} excretion is ≥80% of the infused Mg^{2+} load.

2.2.2 Concentration

- **Dosing of magnesium supplementation should be written in mmol (not grmas or mEq) to avoid potential medication errors**

✓ **Standard Concentrations**
✓ 0.2 mmol /mL in D5W or NS
✓ **Maximum Concentration**
✓ 0.8 mmol /mL in D5W or NS

2.2.3 Infusion Rate

• **Central access**: 4 mmol /30-60 minutes; ensure neurological checks are being performed
• **Peripheral access**: 4 mmol/60 minutes.
- **Maximum infusion rate:**
  - ✓ ICU: (4 mmol) over 10 minutes or 150 mg/min **(0.6mmol / min)**
  - ✓ General ward: 4 mmol over 30 - 60minutes

2.2.4 Mg^{2+} Replacement in Patients with Reduced Kidney Function

- Patients with reduced kidney function may require magnesium repletion if they have severe hypomagnesemia <1 mg/dL (0.4 mmol/L).
- In patients with renal insufficiency (creatinine clearance < 30 mL/min/1.73 m^2): reduce the IV Mg^{2+} dose by 50% or more and closely monitor Mg^{2+} concentrations.
- A symptomatic patient with severe hypomagnesemia whose GFR is 15 to 30 mL/min per 1.73 m^2 should be treated with 2 to 4 g (8 to 16 mmol) of IV magnesium sulfate given slowly over 4 to 12 hours.
- A symptomatic patient who has severe hypomagnesemia and moderately decreased kidney function may be treated with approximately half the normal patient's Mg^{2+} dose orally.

2.2.5 Magnesium Replacement in Patients with Severe Symptoms

Symptomatic patients, such as those with tetany, arrhythmias, or seizures should receive intravenous magnesium. Such patients should have continuous cardiac monitoring.

Table 4: $MgSO_4$ Replacement in Patients with Severe Symptoms

Serum Mg^{2+} Level	Diluent/ Infusion Rate	Total Mg^{2+} Replacement	Renal Dose CrCl < 30 mL/min	Monitoring
Hemodynamically unstable patients (arrhythmias consistent with torsade de pointes or hypomagnesemic hypokalemia)	100 mL NS or D5W	4 to 8 mmol can be given initially over 2 to 15 minutes; may repeat if patient remains unstable Once patient is stable, give an additional 16 to 32 mmol over 12 to 24 hours	4 mmol initially over 60 minutes : may repeat if patient remains unstable	ECG, blood pressure, magnesium & potassium levels 2-hr after the initial dose, then measured 6 to 12 hours after each dose
In hemodynamically stable patients with severe symptoms Mg^{2+} ≤ 1 mg/dL (0.4 mmol/L)	50 to 100 mL of NS or D5W	4 to 8 mmol initially over 5 to 60 minutes followed by an additional 16 to 32 mmol given slowly over 12 to 24 hours	4 mmol initially over 60 minutes followed by 8 mmol in 100 ml NS over 12 to 24 hours	ECG, blood pressure, magnesium & potassium levels 2-hr after the initial dose, then measured 6 to 12 hours after each dose

Abbreviations: CrCL, creatinine clearance; D5W, dextrose 5% in water; NS, normal saline.

2.2.6 Patients with no or Minimal Symptoms

- ✓ Oral replacement should be given to the hypomagnesemic patient with no or minimal symptoms (a typical daily dose in a patient with normal renal function is 240 to 1000 mg (20 to 80 mEq [10 to 40 mmol]) of elemental magnesium in divided doses).
- ✓ Magnesium oxide 800 to 1600 mg (20 to 40 mmol [40 to 80 mEq]) daily in divided doses
- ✓ However, many patients are unable to take oral magnesium or have side effects such as gastrointestinal discomfort and diarrhea.

Table 5: Intravenous Mg^{2+} Replacement in Stable Hospitalized Patients (with no or minimal symptoms)

Serum Mg^{2+} Level	Diluent	Maintenance Dose	Renal Dose CrCl < 30 mL/min	Recheck Level
Mild depletion 1.6 to 1.9 mg/dL 0.7 to 0.8 mmol/L	100 mL NS or D5W	4 to 8 mmol over 2 to 4 hours	2 mmol in 100 mL NS or D5W over 4 hours	With morning labs
Moderate depletion 1 to 1.5 mg/dL 0.4 to 0.6 mmol/L	100 mL NS or D5W	8 - 16 mmol over 4 –12 hours	4 mmol in 100 mL NS or D5W over 6 –12 hours	With morning labs

Severe depletion <1 mg/dL 0.4 mmol/L	100 mL NS or D5W	Bolus 4 to 8 mmol initially over 5 to 60 minutes then ⇩ 16 to 32 mmol over 12 –24 hours	8 mmol in 100 mL NS or D5W over 12–24 hours	2-hours after replacement
	500 mL NS or D5W			

Abbreviations: D5W, dextrose 5% in water; NS, normal saline.

2.3 Hypocalcemia

2.3.1 General Approach to Hypocalcemia Treatment

- ✓ Normal serum Ca^{2+} concentration: 8.5–10.5 mg/dL (2.15 – 2.55 mmol/L); normal serum ionized concentration 1.12–1.25 mmol/L.[3]
- ✓ Serum calcium concentrations of less than 8.6 mg/dL (2.15 mmol/L) are considered to represent hypocalcemia if ionized calcium values are also less than 4.5 mg/dL (1.12 mmol/L).[7]
- ✓ Treatment of the underlying cause of hypocalcemia is the mainstay of management.[7]
- ✓ Emergent treatment of hypocalcemia is rarely warranted unless life-threatening symptoms are present (e.g., frank tetany or seizures).
- ✓ Calcium in serum is bound to proteins (albumin); as a result, total serum calcium concentrations in patients with low or high serum albumin levels may not accurately reflect the ionized (free) calcium concentration, and you should calculate corrected Ca^{2+} level.[12][7]
- ✓ Corrected calcium (mg/dL) = measured total Ca^{2+} (mg/dL) + 0.8 (4.0 - serum albumin [g/dL]), where 4.0 represents the average albumin level.[7]
- ✓ If your total serum calcium is measured by (mmol/L) and albumin (g/L), you should use the factor 0.02 mmol/L instead of 0.8 mg/dL to calculate the corrected calcium level.[7]
- ✓ Magnesium status can influence calcium homeostasis; hypocalcemia will correct within 2 days after hypomagnesemia is corrected. [3]
- ✓ Patients receiving digoxin should be monitored closely for acute digitalis toxicity, which can develop with calcium infusion. [14]
- ✓ IV calcium should be continued until the patient is receiving an effective regimen of oral calcium and vitamin D. For patients with hypoparathyroidism➔calcitriol (in a dose of 0.25 to 0.5 mcg twice daily) and oral calcium (1 to 4 g of calcium carbonate daily in divided doses).
- ✓ In critically ill patients with acid-base imbalance, the ionized serum calcium level will be altered.[7]
- ✓ Ionized serum calcium level should be followed in critically ill patients and corrected total serum calcium determined in patients with hypoalbuminemia (< 4 g/L) .[7]
- ✓ Refractory hypocalcemia should be managed with a continuous infusion of calcium.[7]
- ✓ Calcium gluconate is usually preferred than calcium chloride because it is less likely to cause tissue necrosis if extravasated**.**
- ✓ Administer IV calcium gluconate as **bolus slowly (not to exceed 200 mg (0.46 mmol)/minute**, while **continuous infusion rate should not exceed 10 mg/minute (0.023 mmol / minute).**

2.3.2 Concentration

Standard Concentration: 20 mg/mL (0.046 mmol/ml) for peripheral and central line administration

Maximum Concentration:

50 mg/mL (0.12 mmol /ml) for peripheral line administration

Undiluted 100 mg/mL (0.23 mmol / ml) for **central line** administration

Table 6: Initial Management of Hypocalcemia in Adults Without Chronic Kidney Disease–Mineral and Bone Disorder [7]

Serum Calcium Level (mmol/L)	IV Bolus Dose	Diluent	Duration	Monitoring
Mild – Moderate Corrected Ca^{2+} 1.9 – 2.12 mmol/L Ionized Ca^{2+} 1 – 1.12 mmol/L	2.3 or 4.6 mmol	100 mL NS or D5W	Over 1 – 2 hr	Recheck the level after 12 hours
Severe (asymptomatic) Corrected Ca^{2+} < 1.9 mmol/L Ionized Ca^{2+} < 1 mmol/L	4.6 or 9.2 mmol	100 – 250 mL NS or D5W	Over 2 hr	▪ Recheck the level after 6 hour ▪ Phosphate ▪ Magnesium ▪ Potassium
Acute Severe Symptomatic (e.g., seizure, tetany) Corrected Ca^{2+} < 1.9 mmol/L Ionized Ca^{2+} < 0.8 mmol/L	2.3 or 4.6 mmol Repeat dose every 30–60 minutes until symptoms resolve, followed by a slow infusion in patients with persistent hypocalcemia (e.g., hypoparathyroidism, pancreatitis): IV 0.0125 – 0.037 mmol / kg /hr elemental calcium Or 25 mmol of calcium gluconate in 1000 mL NS or D5W (final	50 -100mL NS or D5W	10 to 20 minutes	▪ ECG ▪ Check the levels 4-hr after the loading dose then every 6 hr ▪ BUN & Creatinine ▪ Albumin ▪ Phosphate ▪ Magnesium ▪ Potassium

	concentration of 0.025 mmol/ml) at rate of of 50 mL/hr (equivalent to 50 mg (1.2 mmol) /hr of elemental calcium).			

Abbreviations: BUN, blood urea nitrogen; D5W, dextrose 5% in water; NS, normal saline.

2.4 Hypophosphatemia

2.4.1 General Approach to Hypophosphatemia Treatment [3] [7]

- Normal serum concentration: 2.5–4.5 mg/dL (0.82 – 1.45 mmol/L)
- Phosphorus (PO_4) is an intracellular electrolyte
- Hypophosphatemia definition: serum phosphorus < 2.5–3 mg/dL (0.82 – 0.97 mmol/L); severe hypophosphatemia < 1–1.5 mg/dL (0.32 – 0.48 mmol/L)
- Target serum phosphorus concentration when patient is in the ICU and ventilator dependent: about 4 mg/dL (1.3 mmol/L).
- Phosphorus should always be ordered in millimoles for ease of use and preparation.
- If potassium phosphate is to be used, intravenous potassium protocol should be followed.

2.4.2 Available Products:[16]

- Sodium phosphate (inorganic): contains phosphate 3 mmol and sodium 4 mmol/mL.
- Potassium phosphate (inorganic): contains phosphate 3 mmol and potassium 4.4 mmol/mL.

2.4.3 PO_4 Replacement:

- Always look at the phosphate level to determine the appropriate K^+ product: KCl (Potassium Chloride), KPO_4 (Potassium phosphate). [7]
- Use ideal body weight (IBW) for dosing if total body weight is > 30% over IBW.
- For creatinine clearance less than 30 mL/min, reduce the phosphate dose by 50%.
- Use sodium phosphate for patients with serum potassium more than 4 mmol/L and serum sodium less than 145 mmol/L.
- Use potassium phosphate for patients with serum potassium less than 4 mmol/L and serum sodium more than 135 mmol/L.
- Repeat serum phosphate level 2–4 hours after each dose.
- If patients have severe hypophosphatemia, two doses of 15 mmol may be given before obtaining a level.
- In case of hypercalcemia, lower the dose by 25% to 50%.
- In patients with renal dysfunction and/or less severe hypophosphatemia, slower administration rates (e.g., over 4 to 6 hours) or oral repletion is recommended.

2.4.4 Infusion Rate

Maximum Rate for Peripheral Line:

- 7 mmol/hour of phosphorus
- 10 mmol/hour of potassium

Maximum Rate for Central Line:

- 15 mmol/hour of phosphorus (as both sodium and potassium phosphate salts) may be used only in severe symptomatic hypophosphatemia emergencies (<0.5 mmol/L).
- When using the potassium phosphate salt, a potassium infusion rate of 22 mmol/hour through a central line needs continuous ECG monitoring if the potassium infusion rate is more than 10 mmol/hr.

2.4.5 Concentration

Standard Concentrations:

Normal saline prefers as diluent to prevent "Internal redistribution (shifts into the cells)

- Potassium phosphate: 15 mmol/250 mL D5W or NS
- Sodium phosphate: 15 mmol/250 mL D5W or NS

Maximum Concentrations:

- Potassium phosphate:
  - **Peripheral line**: 6.5 mmol/100 mL D5W or NS
  - **Central line**: 15 mmol/100 mL with continuous ECG Monitoring
- Sodium phosphate:
  - 15 mmol/100 mL D5W or NS.

Table 7: Phosphate Replacement [3]

Serum Phosphorus (mg/dL) (mmol/l)	General Medical-Surgical Population Dosage (mmol/kg)	High Requirement Population* Dosage (mmol/kg)	Recheck Level
Mild 2 – 2.4 **mg/dL** 0.7 -0.8 **mmol/l**	0.16 over 4 hr **OR** 15 mmol in 250 mL NS over 2 hr	0.32 over 6 hr **OR** 30 mmol in 500 mL NS over 4 hr	With morning labs
Moderate 1-1.9 **mg/dL** 0.3 – 0.6 **mmol/l**	0.32 over 6 hr **OR** 30 mmol in 500 mL NS over 4 hr	0.64 over 8 hr **OR** 45 mmol in 750 mL NS over 6 hr	4-hours after replacement
Severe < 1 **mg/dL** < 0.3 **mmol/L**	0.64 over 8 hr **OR** 45 mmol in 750 mL NS over 6 hr	1 over 12 hr **OR** 60 mmol in 1000 mL NS over 8 hr	4-hours after replacement

*High requirement population: patients with thermal injury, trauma (especially those with a traumatic brain injury), those malnourished with evidence of significant complications from refeeding syndrome, or those with hepatic resection.

3. Appendices

Nurses Adult Electrolyte Replacement Sheets

Potassium Replacement

Table 1: Oral or Enteral Potassium Replacement in Asymptomatic Patients? [7]

Serum K^+ level	Total K^+ replacement (normal renal function)	If CrCL<30 mL/min reduce the dose	Recheck level
3.7 – 3.8 mEq/L	40 mmol stat	No need for replacement	With morning labs, obtain basic metabolic panel
3.4 – 3.6 mEq/L	40 mmol stat	20 mmol stat	6-hours after replacement; if K^+ still low give another 40 mmol stat and repeat with next lab; with next morning labs add magnesium, obtain basic metabolic panel
3.0 – 3.3 mEq/L	Give 40 mmol stat If still under 3.5 give another dose then repeat the result	20 mmol stat	
If serum level < 3.0 mmol/L call physician and consider IV replacement			

Abbreviations: CrCL, creatinine clearance.

Table 2: Intravenous Potassium (K^+) Replacement [7]

Serum K^+ level mEq/L mmol/L	Central line under continuous ECG monitoring	Peripheral line	If CrCL<30 mL/min		Recheck Level
			Central line under continuous ECG monitoring	Peripheral line	
3.6 – 3.8	20 mmol K^+ in 100 mL NS over 1 hr	20 mmol K^+ in 250 mL NS over 2 hr	Not recommended		With morning labs, obtain basic metabolic panel
3.0 – 3.5	40 mmol K^+ in 200 mL NS over 2 hr	40 mmol K^+ in 500 mL NS over 4 hr	20 mmol K^+ in 100 mL NS over 1 hr	20 mmol K^+ in 250 mL NS over 2 hr	Recheck the level 2-hours after replacement and reassess, also with next morning labs add magnesium and basic metabolic panel
2.5 – 2.9	60 mmol K^+ in 300 mL NS over 3 hr	40 mmol K^+ in 500 mL NS over 4 hr followed by 20 mmol K^+ in 250	20 mmol K^+ in 100 mL NS over 2 hr, then recheck the level 2-hours after replacement	20 mmol K^+ in 250 mL NS over 2 hr, then recheck the level 2-	2-hours after replacement and adjust treatment accordingly

		mL NS for 2 hr		hours after replacement	
< 2.5 or symptomatic	40 mmol K^+ in 100 mL NS over 1 hr	40 mmol K^+ in 500 mL NS over 4 hr	40 mmol K^+ in 200 mL NS over 2 hr	40 mmol K^+ in 500 mL NS over 4 hr	After each 40 mmol replacement and adjust treatment accordingly

Abbreviations: CrCL, creatinine clearance; NS, normal saline.

Magnesium Replacement

Table 3: $MgSO_4$ Replacement in Patients with Severe Symptoms

Serum Mg^{2+} Level	Diluent/ Infusion Rate	Total Mg^{2+} Replacement	Renal Dose CrCl < 30 mL/min	Monitoring
Hemodynamically unstable patients (arrhythmias consistent with torsade de pointes or hypomagnesemic hypokalemia)	100 mL NS or D5W	4 to 8 mmol can be given initially over 2 to 15 minutes; may repeat if patient remains unstable Once patient is stable, give an additional 16 to 32 mmol over 12 to 24 hours	4 mmol initially over 60 minutes; may repeat if patient remains unstable	ECG, blood pressure, magnesium & potassium levels 2-hr after the initial dose, then measured 6 to 12 hours after each dose
In hemodynamically stable patients with severe symptoms Mg^{2+} ≤ 1 mg/dL (0.4 mmol/L)	50 to 100 mL of NS or D5W	4 to 8 mmol initially over 5 to 60 minutes followed by an additional 16 to 32 mmol given slowly over 12 to 24 hours	4 mmol initially over 60 minutes followed by 8 mmol in 100 mL NS over 12 to 24 hours	ECG, blood pressure, magnesium & potassium levels 2-hr after the initial dose, then measured 6 to 12 hours after each dose

Abbreviations: CrCL, creatinine clearance; D5W, dextrose 5% in water; NS, normal saline.

Table 4: Intravenous Mg Replacement in Stable Hospitalized Patients (with no or minimal symptoms)

Serum Mg^{2+} Level	Diluent	Maintenance Dose	Renal Dose CrCl < 30 mL/min	Recheck Level
Mild depletion 1.6 to 1.9 mg/dL 0.7 to 0.8 mmol/L	100 mL NS or D5W	4 to 8 mmol over 2 to 4 hours	2 mmol in 100 mL NS or D5W over 4 hours	With morning labs
Moderate depletion 1 to 1.5 mg/dL 0.4 to 0.6 mmol/L	100 mL NS or D5W	8 - 16 mmol over 4 –12 hours	4 mmol in 100 mL NS or D5W over 6 –12 hours	With morning labs

Severe depletion <1 mg/dL 0.4 mmol/L	100 mL NS or D5W 500 mL NS or D5W	Bolus 4 to 8 mmol initially over 5 to 60 minutes then 16 to 32 mmol over 12 –24 hours	8 mmol in 100 mL NS or D5W over 12–24 hours	2-hours after replacement

Abbreviations: D5W, dextrose 5% in water; NS, normal saline.

Calcium Replacement

Table 5: Initial Management of Hypocalcemia in Adults Without Chronic Kidney Disease–Mineral and Bone Disorder [7]

Serum Calcium Level (mmol/L)	IV Bolus Dose	Diluent	Duration	Monitoring
Mild – Moderate Corrected Ca^{2+} 1.9 – 2.12 mmol/L Ionized Ca^{2+} 1 – 1.12 mmol/L	2.3 or 4.6 mmol	100 mL NS or D5W	Over 1 – 2 hr	Recheck the level after 12 hours
Severe (asymptomatic) Corrected Ca^{2+} < 1.9 mmol/L Ionized Ca^{2+} < 1 mmol/L	4.6 or 9.2 mmol	100 – 250 mL NS or D5W	Over 2 hr	▪ Recheck the level after 6 hour ▪ Phosphate ▪ Magnesium ▪ Potassium
Acute Severe Symptomatic (e.g., seizure, tetany) Corrected Ca^{2+} < 1.9 mmol/L Ionized Ca^{2+} < 0.8 mmol/L	2.3 or 4.6 mmol Repeat dose every 30–60 minutes until symptoms resolve, followed by a slow infusion in patients with persistent hypocalcemia (e.g., hypoparathyroidism, pancreatitis): IV 0.0125 – 0.037 mmol / kg /hr elemental calcium Or 25 mmol of calcium gluconate	50 -100mL NS or D5W	10 to 20 minutes	▪ ECG ▪ Check the levels 4-hr after the loading dose then every 6 hr ▪ BUN & Creatinine ▪ Albumin ▪ Phosphate ▪ Magnesium ▪ Potassium

	in 1000 mL NS or D5W (final concentration of 0.025 mmol/ml) at rate of of 50 mL/hr (equivalent to 50 mg (1.2 mmol) /hr of elemental calcium).			

Abbreviations: BUN, blood urea nitrogen; D5W, dextrose 5% in water; NS, normal saline.

Phosphate Replacement

Table 6: Phosphate Replacement [3]

Serum Phosphorus (mg/dL) (mmol/l)	General Medical-Surgical Population Dosage (mmol/kg)	High Requirement Population* Dosage (mmol/kg)	Recheck Level
Mild 2 – 2.4 **mg/dL** 0.7 -0.8 **mmol/l**	0.16 over 4 hr **OR** 15 mmol in 250 mL NS over 2 hr	0.32 over 6 hr **OR** 30 mmol in 500 mL NS over 4 hr	With morning labs
Moderate 1-1.9 **mg/dL** 0.3 – 0.6 **mmol/l**	0.32 over 6 hr **OR** 30 mmol in 500 mL NS over 4 hr	0.64 over 8 hr **OR** 45 mmol in 750 mL NS over 6 hr	4-hours after replacement
Severe < 1 **mg/dL** < 0.3 **mmol/L**	0.64 over 8 hr **OR** 45 mmol in 750 mL NS over 6 hr	1 over 12 hr **OR** 60 mmol in 1000 mL NS over 8 hr	4-hours after replacement

*High requirement population: Patients with thermal injury, trauma (especially those with a traumatic brain injury), those malnourished with evidence of significant complications from refeeding syndrome, or those with hepatic resections

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